Final Technical Report

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Title: A proposal to complete the analysis of the Lincoln aftershocks recorded by the Montana Regional Seismograph Network

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Abstract

A magnitude 5.8 earthquake occurred on July 6, 2017 and was centered 13 km southeast of Lincoln, Montana. A vigorous aftershock overwhelmed the analysis capabilities of the Earthquake Studies Office of the Montana Bureau of Mines and Geology, operator of the Montana Regional Seismograph Network. Funding from this agreement supported an undergraduate student to assist with picking seismic phase arrival times and determining preliminary locations and magnitudes for earthquakes in the early weeks of the Lincoln aftershock sequence. We have determined final locations for 2,091 aftershocks that occurred during the first two months of the Lincoln earthquake aftershocks sequence.

Report

The largest Montana earthquake in 58 years occurred on July 6, 2017; it was also the largest earthquake in the lower 48 states during 2017. It was centered 13 km southeast of the town of Lincoln (population ~1,000) and 52 km northwest of Helena, the state capitol (population 31,400). The Lincoln earthquake produced intensity VIII shaking on the Modified Mercalli Intensity Scale near the epicenter, caused a power outage in Lincoln, toppled items from shelves within 100 km of the epicenter, and was reported felt at locations more than 800 km from the epicenter. Due to the relatively remote epicenter location, no injuries or serious damage was reported.

The Lincoln earthquake occurred within the Montana Regional Seismograph Network (MRSN) but the closest station was 21 km from the main shock epicenter. Six MRSN stations lie within 58 km of the main shock and provide good azimuthal control of epicenter locations (Figure 1). The main shock focus had a depth of 13.6 km below sea level and the majority of aftershocks occurred between 10 and 15 km deep. Because the MRSN stations provided less than optimal focal depth control, the US Geological Survey deployed three temporary seismograph stations in the epicentral area (Figure 1). The first temporary station was recording data 57 hours after the main shock. Data from the three temporary stations were archived in real-time at the IRIS Data Management Center, from which the Montana Bureau of Mines and Geology imported these data to the MRSN analysis stream and used them to better constrain aftershock hypocenters.

The MRSN records seismic data using Earthworm software which also produces event triggers and automatic locations. With generous assistance from the University of Utah Seismograph Stations, MRSN data are incorporated into an AQMS database running in Utah. We use Jiggle software (Figure 2) to analyze all local and regional seismic events recorded by the MRSN. The MRSN produced triggers for most Lincoln aftershocks with magnitudes of 1.0 or larger. We located 1,230 aftershocks that occurred during the first week, 1,738 during the first month, and 2,091 during the first two months of the aftershock sequence. This level of seismicity simply overwhelmed the analysis capabilities of the one-person staff operating the MRSN. Within a month of the main shock, seismicity rates had slowed to the point that I could keep up with daily analysis loads. However, there was a backlog of well over 1,000 events that needed to be picked and located. All of the funding from this cooperative agreement was used to hire a Montana Tech undergraduate student, Mr. Andrew Wilson, a junior majoring in Geophysical Engineering, to assist with the analysis of backlogged events. After several days of training in the use of Jiggle software, Mr. Wilson worked part-time from January through May, 2018 to produce

preliminary locations and magnitudes for the unprocessed backlog of events. I review all preliminary hypocenter locations and magnitudes before contributing them to the ANSS Composite Catalog.

Project Data

All earthquake phase picks, hypocenter locations, and magnitudes are contributed to the ANSS Composite Catalog. Continuous waveforms for all MRSN stations are archived in real-time at the IRIS Data Management Center. Response files for all MRSN stations are available from the IRIS Data Management Center. MRSN catalog data are also available by request from the Montana Bureau of Mines and Geology.

Bibliography

Because this cooperative agreement supported basic data analysis, no publications resulted from this project.

Figures

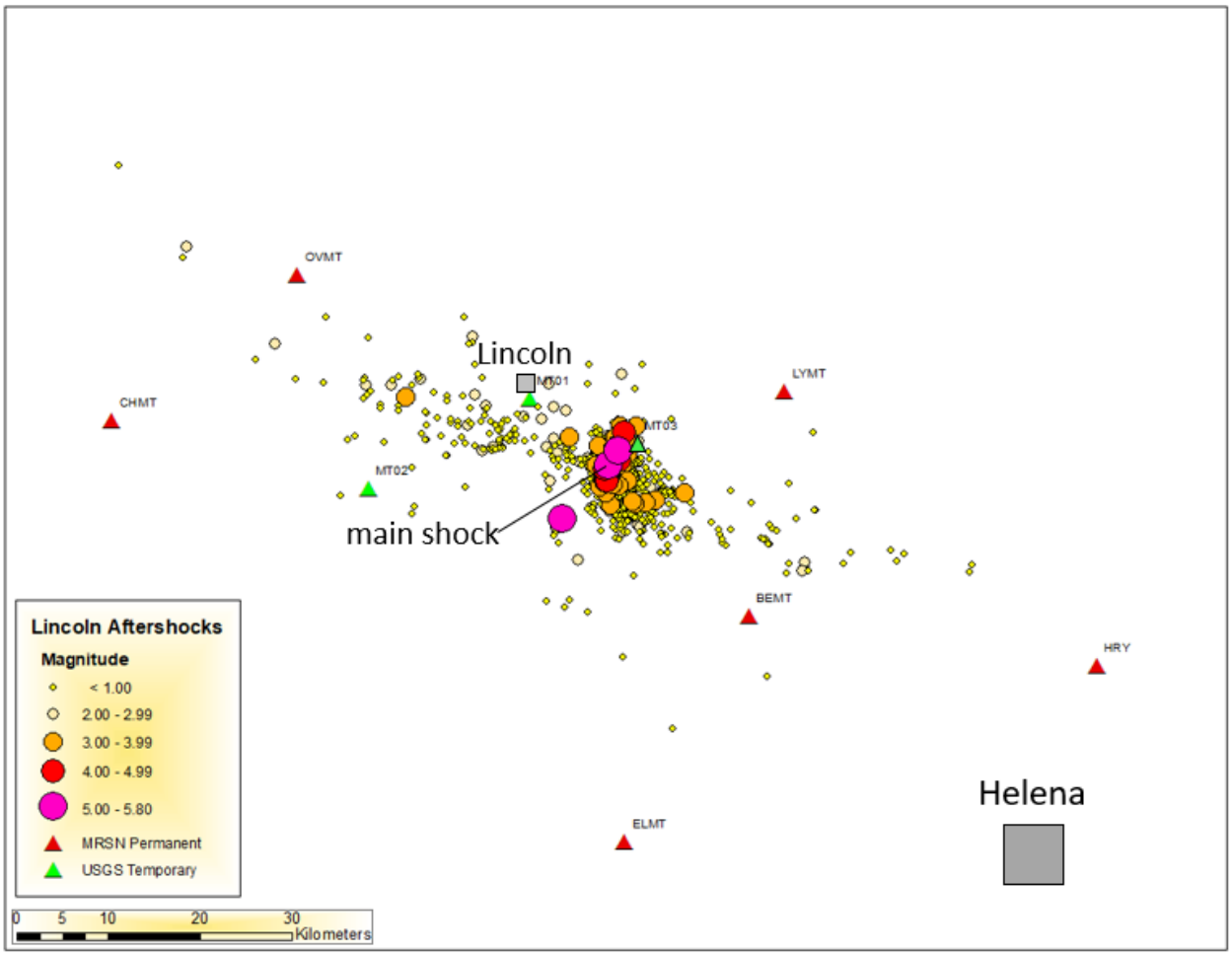

Figure 1. Map showing 2,091 aftershock epicenters located with Montana Regional Seismograph Network (red triangles) and USGS temporary network (green triangles) data during the first two months of the Lincoln aftershock sequence.

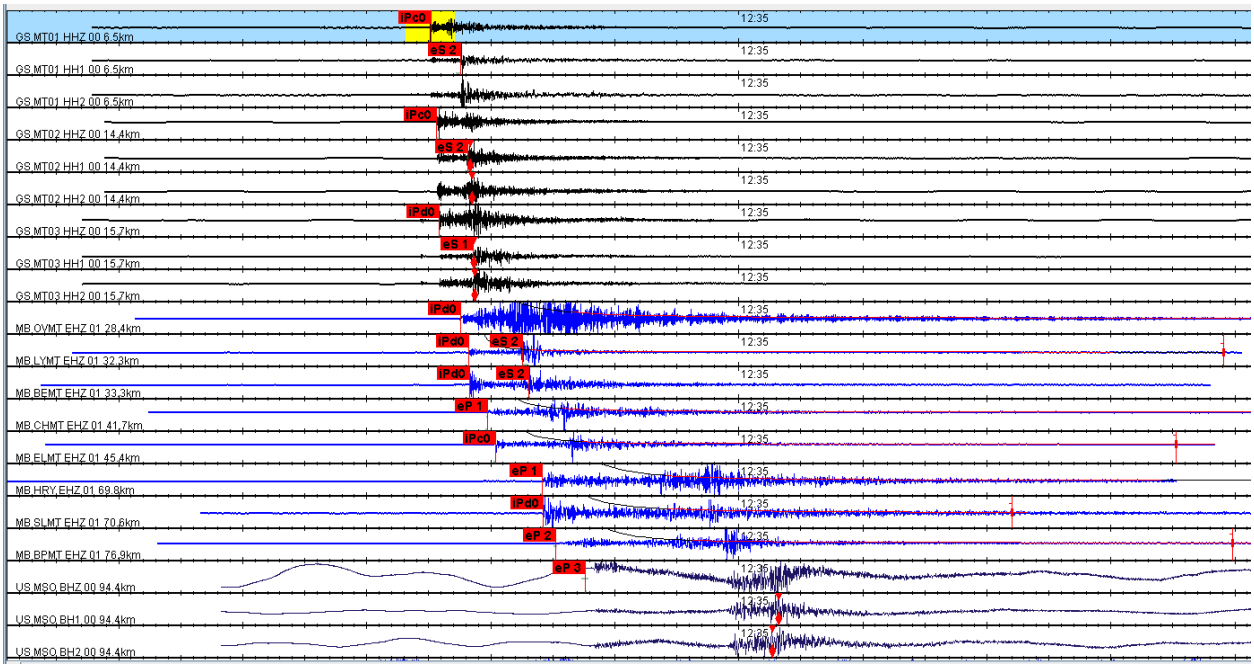

Figure 2. Screen shot from Jiggle software showing about 90 seconds of waveform data and picks from the 12 closest seismograph stations to a magnitude 2.3 Lincoln aftershock that occurred July 17, 2017 at 12:34 UTC.